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THE ORGANISM AS PHŒNIX.

(1) *Senescence and Rejuvenescence.* By C. M. Child. Pp. xi+481. (Chicago: University of Chicago Press; London: Cambridge University Press, 1915.) Price 16*s.* net.

(2) *Individuality in Organisms.* By C. M. Child. Pp. x+213. (Chicago: University of Chicago Press; London: Cambridge University Press, 1915.) Price 5*s.* net.

(1) IN this able study of senescence and rejuvenescence Prof. Child gives us the fruits of fifteen years of research on the age-changes of the lower animals. Much of the book is a record of observations and experiments which have not been previously published; the rest is a thoughtful working-out of a new conception of the organism, which must be taken account of by all biologists. The most prominent new feature is the author's attempt to show that "in the organic world in general rejuvenescence is just as fundamental and important a process as senescence." In the higher forms the possibilities of rejuvenescence seem to be very narrowly limited, and may be scarcely recognisable save in connection with sexual reproduction; but in the simpler organisms, such as the Planarian worms on which the author has published many researches, it is a characteristic feature of life.

In seeking to determine the degree of ageing in an organism we are accustomed to look out for certain structural changes familiar in man and mammals, or we measure the decreasing rate of metabolism per unit of substance. For lower animals, however, other tests must be used; thus advantage has been taken of the general relation between metabolic condition and susceptibility or resistance to cyanides or other narcotics. With differences in susceptibility there also correspond differences in carbon dioxide production as estimated by Tashiro's beautifully delicate "biometer." In other cases the susceptibility or resistance of the organism to the depressing agent may be determined indirectly by the creature's ability to become acclimated to a given concentration.

Numerous experiments on Planarians show that the rate of metabolism, measured by the susceptibility method, decreases with advancing age, and it is concluded that a decrease in rate of metabolism is at least very generally associated with growth and differentiation. An isolated fragment of a Planarian begins by developing a new head and tail, and then undergoes an extensive reorganisation into a new individual of small size. Some parts atrophy and disappear; new parts arise and differentiate; the development in reconstitution is not essentially different from embryonic development. All this and much more is familiar, but the novel point is that the reconstituting Planarians are physiologically younger than those from which the pieces came. As measured by the susceptibility method they exhibit rejuvenescence, and "the degree of rejuvenescence is in general proportional to the degree of reorganisation in the process of reconstitution of the piece into a whole" (p. 118).

The next step in the experimental argument is very interesting: it is the demonstration (by the susceptibility method) that pieces spontaneously isolated in Planarians and Hydroids are physiologically younger than the individuals from which they separate. In other words, rejuvenescence is associated with asexual or agamic reproduction. Furthermore, a Planarian starved for months lives on its own resources and becomes reduced in size. Some cells disappear and others become small. This is well known, but the new fact is that the starving animals undergo rejuvenescence, the degree varying with the degree of reduction. If the susceptibility method is trustworthy they become physiologically younger, and this conclusion was corroborated by estimating the production of carbon dioxide. There is here a strong biological argument for asceticism. The starveling is brought back from an advanced age to the beginning of post-embryonic life; it is almost reborn. "The metabolic current is forced to erode its channel instead of depositing material along its course" (p. 179). Moreover, with certain foods a progressive senescence from generation to generation occurs, while with other foods senescence and rejuvenescence seem to balance in each cycle.

In plants and simple animals, such as polyps, asexual reproduction is frequent, and this brings with it some measure of rejuvenescence. "Often the decrease in metabolic rate with advancing senescence is the primary factor in bringing about physiological isolation of parts, reproduction, and rejuvenescence" (p. 260), and thus senescence may be automatically compensated for. Of great interest, also, are various processes of cellular dedifferentiation which occur in both plants and lower animals, and this also will act as a retardation of senescence. In the higher animals the later atrophic stages of senescence are conspicuous, while in the lower forms they either do not appear or else occur in only a few cells at any given time. "The apparent continuity and irregressibility of senescence in man and the higher forms is responsible for the very general belief that the process is irregressible everywhere, but the plants and lower animals show us clearly enough that this is not the case" (p. 289). In the higher reaches senescence is less frequently interrupted, but it is essentially the same throughout, and occurs "wherever the progressive changes are not balanced or overbalanced by regression." With senescence in man and domesticated mammals everyone is familiar, but what of the alleged rejuvenescence? The author answers that some degree of rejuvenescence occurs in certain tissues, but that on the whole it is grievously limited by the greater stability of the substratum. "For his high degree of individuation man pays the penalty of individual death, and the conditions and processes which lead to death in the end are the conditions and processes which make man what he is" (p. 310).

It might seem that the author's thesis was here petering out, but the next step is important. Prof. Child does not believe much in the "segregation of the germ-plasm"; he thinks that the germ-cells, like the somatic cells, exhibit progressive differentiation and senescence, that "the fully developed gametes are physiologically old, highly differentiated cells, which are rapidly approaching death and in most cases actually do die soon after maturity unless fertilisation occurs" (p. 357). They are of advanced physiological age and low metabolic rate. They must undergo de-differentiation and rejuvenescence before they can enter upon a new period of development. The parthenogenetic egg has not lost its capacity of reacting to isolation, but ordinary gametes can undergo de-differentiation and reconstitution only after fertilisation. In this ingenious way, which cannot be justly represented in brief statement, the author interprets gamete formation as a means of securing rejuvenescence. Reproduction is always the reconstitution of a new organism from a part of one previously existing, but the author stands for the new idea that rejuvenescence occurs during early development, and the zoological evidence that he adduces is very interesting. "The organism, when it begins its active independent life at the end of the embryonic period, is certainly very much younger in every respect than the gametes before fertilisation" (p. 403). It has become younger as it has grown older. This seems a little over-ingenious, but the general idea that the early development means very literally making a fresh start becomes concrete and vivid in the author's exposition.

Let us attempt a more compact statement of the author's interpretation of age-changes. The numerous theories of senescence fall into two groups—those which regard it as an incidental imperfection (due to wear and tear, incomplete elimination of waste products, and so on), and those which regard it as an inevitable feature of development. Prof. Child's experiments point to the second view. After the earliest stages of development there is a progressive change in the direction of greater physiological stability in consequence of changes in the substratum and additions to it in the course of growth and differentiation. As the proportion of relatively stable constituents in the substratum increases, there is a decrease in the metabolic activity of each unit of weight or volume of the organism. Thus cells may become loaded with non-protoplasmic enclosures, and skeletal or supporting tissues arise. It is also probable that the increasing density and aggregation of the colloid substratum may lead to an actual decrease in the rate of chemical reactions, and that the increase in density and thickness and the decrease in the permeability of membranes may retard the exchange through them. Thus and thus does ageing begin while the life is still young. "The decrease in rate of metabolism is a part of development itself, and not an accidental or incidental feature of life. The decrease in metabolic rate during development is in fact a necessary and inevitable consequence of the association of the chemical reactions which constitute metabolism with a colloid substratum produced by the reactions" (p. 184). But there is another side to all this, which has been for the most part overlooked because it is inconspicuous in higher forms. There are processes of reduction as contrasted with growth, of retrogressive as contrasted with progressive development. Accumulated substances and structures may be broken down, and the self-fettered metabolism increases in rate. There is a retrogression towards the embryonic condition, as is familiarly seen in the pupa of a fly. "Dynamically rejuvenescence consists in increase in rate of metabolism, and morphologically in the changes in the substratum which permit increase in rate." And this rejuvenescence is as essential a feature of life as senescence. Ageing has been too much regarded as "a rather mysterious process, quite different from anything else in the life cycle," but it is simply a conspicuous expression of what occurs in minor rhythms continually. Thus the period of "loading" of a gland-cell is a period of decreasing metabolic activity (of "senescence"), and the period of discharge one of increasing activity (of "rejuvenescence"), which makes possible a repetition of the cycle. So there are alternations of fatigue and recovery, of quiescence and activity, and "whether we call one cycle an age-cycle and another something else is of little importance, except as regards convenience." It is further suggested that there may be secular senescence and rejuvenescence in racial evolution. "The age-changes in the organism are merely one aspect of *Werden und Vergehen,* the becoming and passing away, which make up the history of the universe."

It is out of the question to express in a few lines more than an appreciation of a carefully executed piece of work of this magnitude. It is rich in suggestiveness and original ideas, and gives us a new view of the organism and its vital tides. Much depends on the soundness of the susceptibility method of determining the rate of metabolism, for a great deal of the evidence relies on this. We confess to a feeling that the superstructure of interpretation is too broad for the Planarian basis on which it mainly rests. Time is required for a consideration of the evidence given of rejuvenescence in the early stages of development in higher animals, and for weighing the author's reasons for rejecting Weismann's conception of the apartness of the germ-plasm. But it is a great satisfaction to meet with such a fine instance of resolute biological thinking, and we offer Prof. Child our congratulations.

(2) The author's main contribution to the problem of organic individuation is the demonstration of a distinct gradient in the rate of metabolic reactions along the chief axis of various axiate types. The apical or head region is primarily the region of highest rate of metabolism, and, in general, regions nearer to it have a higher rate than regions farther away. Moreover, in experimental

reproduction, "the apical or head region develops independently of other parts, but controls or dominates their development, and in general any level of the body dominates more posterior or lower levels and is dominated by more anterior or apical levels." The dominance depends primarily upon the rate of metabolism, and seems to operate by impulses, excitations, or changes transmitted in various ways from the dominant region to other parts of the body.

What Prof. Child seeks is a dynamic conception of the organism, and he maintains that "the individual is primarily a metabolic gradient in a specific protoplasm; the only primary difference between the dominant and other levels of the gradient is a difference of metabolic rate. At this time the products of metabolism at different levels of the gradient are not specifically different, but differ in quantity." But the differences in rate at different levels bring about, sooner or later, differences in constitution and character of the protoplasmic substratum. Here one stable substance and there another remains as a constituent of the colloid substratum. Thus "each level of the gradient develops a characteristic protoplasm, and the character of the protoplasm in turn modifies and alters the character of the reactions, and so specific, or what we call qualitative, differences arise, and different specific substances may be produced at different levels of the gradient." Then for the first time chemical or transportative correlation in the commonly accepted sense becomes possible. The individual is there before the orderly specificities of chemical correlation are present or possible. "The starting point in differentiation is in differences in metabolic rate." The organism is a dynamic reaction system—"a protoplasm of specific constitution with a corresponding metabolic specificity." Individuation is a relation of dominance and subordination of parts. Development is a realisation of the capacities or possibilities which are given in the physico-chemical constitution of the fundamental reaction system. We have said enough to indicate the trend of the author's exceedingly interesting theory, which is doubtless a good one to work with, though it seems to our prejudiced vision to leave half of the Prince of Denmark out of the play. For, colloid substratum and metabolic gradient notwithstanding, we must regard even Prof. Child's Planarians as psycho-physical beings, mind-bodies or body-minds as you will, but organisms as well as mechanisms through and through.

HYDRAULIC FORMULA RECONSTRUCTION.

Hydraulic Flow Reviewed. By A. A. Barnes. Pp. xi+158. (London: E. and F. N. Spon, Ltd., 1916.) Price 12*s.* 6*d.* net.

THE book is in two parts, the first of which deals with the flow of water in pipes and channels. The author had occasion to investigate certain conditions of flow in the Thirlmere aqueduct, which supplies water to Manchester, and, finding the variation in the coefficients of accepted formulæ unsatisfactory, he was led to review the whole subject of the laws of flow, with the result that he has devised a series of formulæ in which the coefficient is independent of variations in the size or gradient of the conduit. Taking the equations of five well-known experimentalists, which he styles "the more salient formulæ" on the subject, he shows that they are of the form $=\mathrm{K}m^{\frac{1}{2}}i^{\frac{1}{2}}$. He then points out that the square root indices of m (the hydraulic mean depth) and of i (sine of slope) are incompatible with a constant value for the coefficient k, for a particular class of pipe or channel. In accordance with the precedent set by Hagen and followed by Thrupp and others, he recommends the adoption of the more general expression $v=\mathrm{K}m_{\alpha}i^{\beta}$, and from the analysis of a considerable number of published data he is enabled to assign a series of values to K, α, and β which give consistent and satisfactory results when applied to a wide range of cases. The formulæ thus obtained are sixteen in number, of which we only quote the first as typical of the rest. For new asphalted cast-iron pipes the value is $v=174{\cdot}1m^{\cdot769}i^{\cdot529}$. The results are plotted in diagrammatic form for reference, and the advantages of using a system of logarithmic co-ordinates (which give straight-line diagrams) for this purpose are pointed out.

In the second part of the book, dealing with the measurement of water by means of triangular notches, rectangular weirs, and circular orifices, the author discards the basic expression in common use, and advocates the application of the general formula adopted in part i., which he casts in the form $v=\mathrm{K}m^{\alpha}\mathrm{H}^{\beta}$. For a right-angled V notch this becomes:—

$$v=2{\cdot}462m^{-\cdot00703}\mathrm{H}^{\cdot48703}$$

whence $\mathrm{Q}=2{\cdot}48\mathrm{H}^{2\cdot48}$.

It is interesting to note that this latter expression corresponds very closely with the results obtained quite recently by Messrs. Gourley and Crimp in researches made on the river Alwen. Their formula reads:—

$$\mathrm{Q}=2{\cdot}48n\mathrm{H}^{2\cdot47}$$

(n is the tangent of half the included angle of the notch, and, therefore, is unity for a notch of 90°).

For weirs with end contractions Mr. Barnes has determined:—

$$v=3{\cdot}324m^{\cdot11}\mathrm{H}^{\cdot38},$$

and for weirs without end contractions:—

$$v=3{\cdot}324m^{-\cdot02}\mathrm{H}^{\cdot51},$$

while for circular orifices:—

$$v=4{\cdot}652m^{-\cdot015}\mathrm{H}^{\cdot5}.$$

There are a large number of authenticated results incorporated in the volume, tabulated in support of these equations, as well as plates giving the results graphically. The author claims that his formulæ are proved correct by experiment for quantities as small as 0·0034 cubic foot per second, by means of orifices, and as large as 320 cubic feet per second, by means of weirs.